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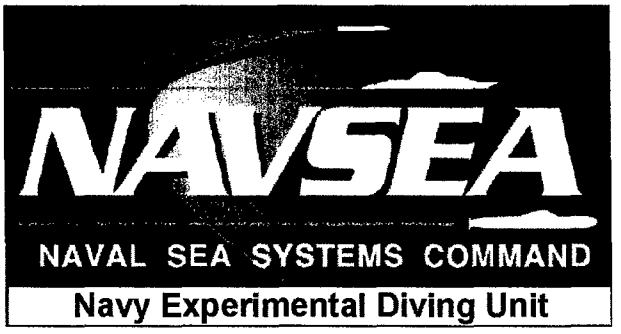
COMPARISON OF HUMAN FACTORS CHARACTERISTICS OF THE KIRBY MORGAN™ 37 AND MK 21 HELMETS DURING A CHAMBER DIVE TO 380 FSW



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The human factors characteristics of Kirby Morgan™ 37 (KM 37) and U.S. Navy MK 21 diving helmets were compared. Both helmets were derived from the Kirby Morgan KM 17 A/B helmets, except that the KM 37 used a new Tri-Valve™ Exhaust System and a neck dam/neck ring assembly, chin support, and neck pad from the Kirby Morgan 21 helmet. The KM 37 and MK 21 helmets both used the same demand regulator. Immersed in 10 ft of water in a hyperbaric chamber pressurized to 370 feet of seawater, eight male U.S. Navy divers performed one dive with each helmet. Breathing gas was a 96% helium, 4% oxygen mix, and water temperature was 35 ± 2 °F. Diver dress consisted of a hot water suit, gloves, and hood. For each helmet doffing and donning, divers used a six-point category scale to rate their comfort, vision, ability to communicate, and parts accessibility and operability. A 12-point category ratio scale was used to obtain subjective ratings of respiratory effort for each helmet. Divers were not kept blind from the helmet they dived. Calculation of inferential statistics was inappropriate, due to the small number of divers relative to the large number of the characteristics rated and the narrow range of categorical ratings within each characteristic. Overall diver ratings of helmet characteristics tended to favor the KM 37 over the MK 21. On the average, the KM 37 was rated slightly better for doffing and donning, for diving vision and comfort, for parts accessibility and operability, and for requiring less respiratory effort than the MK 21. However, the MK 21's noise levels and communications were rated slightly better than those of the KM 37. No statistically significant difference was observed between the specific form, fit, and function characteristics of the helmets.

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TABLE OF CONTENTS

INTRODUCTION

Navy Experimental Diving Unit (NEDU), Panama City, FL, was tasked to evaluate the Kirby Morgan™ 37 (KM 37) diving helmet (Kirby Morgan Dive Systems, Inc.; Santa Maria, CA) for manned diving.[1] The KM 37 is a commercially available design that incorporates features from both the SuperLite 17A/B and the SuperLite 27 helmets.[2,3] The KM 37 uses the same SuperFlow™ 350 demand regulator as the MK 21 — a modified SuperLite 17 currently in U.S. Navy use.[4] Two major assemblies comprise the KM 37: the helmet shell/helmet ring assembly and the neck dam/neck ring assembly. The chrome-plated, machined brass helmet ring includes an externally adjustable chin support. The neck dam/neck ring assembly includes a latch system of two spring-loaded pull pins pulled forward to release the neck collar and neck dam locking system. The chin support and an adjustable neck pad on the locking collar allow the diver to custom fit the helmet. The manufacturer reports that the new Tri-Valve™ Exhaust System presents less breathing resistance than the older single valve exhaust system.

The KM 37 is a candidate to become an approved replacement for the MK 21 diving helmet. The purpose of this test was to compare the human factors characteristics (breathing, overall comfort, and ease of use and operation) of the KM 37 versus those of the MK 21 during a dive to 380 feet of seawater (fsw).[1] Diver evaluations of the helmets focused on their form, fit, and function (comfort, use, and operability). Tests under this protocol did not represent the full battery generally performed to support a recommendation for inclusion on the diving equipment Authorized for Navy Use (ANU) list.

METHODS

GENERAL

This study was performed on the first day of a 16-day helium-oxygen ($He-O_2$) saturation dive. Compression to the test depth of 380 fsw (370 fsw storage depth plus 10 fsw immersion in fresh water) was performed in accordance with standard U.S. Navy diving procedures.[4] Breathing gas was a 96%-4% $He-O_2$ mix. Ocean Simulation Facility (OSF) water temperature was regulated at 35 ± 2 °F. Diver dress consisted of a hot water suit, gloves, and hood. Hot water temperature at the suit inlet did not exceed 110 °F.

Subjects

After reading and signing a consent form documenting that they understood the risks involved in the study and that their participation was voluntary, eight male U.S. Navy divers participated in test dives. Each diver made two dives for a total of 16 dives. All subjects met the U.S. Navy physical qualification standards for diving. Subjects previously trained to use the MK 21 were specifically trained and authorized to use the KM 37 helmet. All had a current saturation diving medical physical (including a neurological examination

the morning of the dive) and were cleared for diving by the Dive Watch Medical Officer (DWMO). Dive team members were requested to abstain from using nicotine products for at least 30 days before the dive.

Procedures

Diver-subjects were divided into four two-man dive teams. Each team member performed two dives immersed in water in the wetpot of the NEDU OSF — one diver with the KM 37 helmet and one diver with the MK 21 helmet. Each diver served as a standby diver for the other.

Dive teams completed the steps listed below.

1. Dive team members donned helmets and performed surface checks to ensure that all equipment was operating properly.

2. Divers entered the water and performed in-water checks.

3. The Dive Watch Supervisor (DWS) instructed divers to perform actions to assess helmet comfort and operation. Actions included:

    a. standing upright,
    b. lying supine,
    c. lying prone,
    d. running in place, and
    e. climbing up and down a ladder.

4. Divers exited the water, removed their helmets, and completed a human factors questionnaire.

5. Divers switched helmets and repeated steps 1 through 4.

After one team had evaluated each helmet, another dive team was prepared and dived both helmets. Each diver adjusted the helmets for individual comfort.

Human Factors Questionnaire for Diving Helmets

The questionnaire (Appendix A) was similar to ones used on previous protocols for evaluating the form, fit, and function of face masks.[5,6] The questionnaire was printed on waterproof paper, allowing the divers to mark their responses with a grease pencil immediately after exiting the water. For each helmet, 27 characteristics were grouped into six categories and assessed. Characteristics of five categories (Doff and Don; Comfort while Diving; Access and Operability; Vision while Diving; Noise Levels and Communication) were rated with a six-point category scale (Table 1). Characteristics of

the sixth category (Respiratory Effort) at rest and during exercise were obtained with a 12-point category ratio scale (Table 2).[7] The rating of respiratory effort during moderate exercise was obtained while the diver ran in place at a pace of approximately two steps · second^{-1}, — i.e., so that the time between two plantings of the same foot was approximately one second. Using his rating during moderated exercise, the diver was asked to estimate his rating of respiratory effort during heavy exercise. Diver-subjects were specifically instructed to report only their degree of breathing effort required to breathe the helmet, not their personal fatigue level. Divers were not kept blind to the helmet they were diving.

Table 1. Six-point category scale used to quantify the human factors characteristics of a diving helmet.

6	Excellent
5	Good
4	Adequate
3	Not Quite Adequate
2	Poor
1	Extremely Poor

EXPERIMENTAL DESIGN AND ANALYSIS

Descriptive statistics (mean, standard deviation [SD], and 95% confidence interval around the mean [95%CI]) were calculated for each rated characteristic of each helmet. Calculation of inferential statistics was inappropriate, because of the small number of divers relative to the large number of the characteristics rated and because of the narrow range of categorical ratings within each characteristic.

Table 2. Twelve-point Category Ratio Scale (Modified Borg Scale) Used to Quantify a Diver's Respiratory Effort.

10	Maximal
9	Very, very severe
8	
7	Very severe
6	
5	Severe
4	Somewhat severe
3	Moderate
2	Slight
1	Very slight
0.5	Very, very slight
0	Nothing at all

RESULTS

Each diver's ratings of the Human Factors Questionnaire and results of a descriptive analysis of the data are presented in Appendix B and Tables 3 through 12, respectively. For the MK 21 the mean characteristic ratings in all categories except "Respiratory Effort" ranged from "Not quite adequate" or "Adequate" (3.6) to "Good" (4.9). Ratings of respiratory effort characteristics ranged from "Very, very slight" (0.4) to "Very slight" (1.0). For the KM 37 helmet the mean rating of the characteristics in all categories except "Respiratory Effort" ranged from "Adequate" (4.1) to "Adequate" or "Good" (5.5). Ratings of respiratory effort characteristics ranged from 0.3 to 0.7 — i.e., "Very, very slight."

Except for "Noise Level and Communication" and "Respiratory Effort," the mean rating of each KM 37 characteristic was equal to or slightly greater than the rating for the corresponding characteristic of the MK 21 (the average difference in rating ranged from 1.4 to 0). The mean rating of "Noise Level and Communication" and "Respiratory Effort"

characteristics for the KM 37 versus the MK 21 ranged from –0.4 to –0.1. Except for "Respiratory Effort," the magnitude of the difference (MK 21 – KM 37) between the mean rating of the categories for the KM 37 versus the MK 21 ranged from 0.2 to 0.8.

Table 3. Descriptive Statistics of Ratings of Dress-out Characteristics for MK 21 and KM 37 Helmets.

		DON AND DOFF				
		Ease of donning neck dam/ring assembly?	Ease of positioning the head cushion?	Ease of donning helmet WITH assistance?	Ease of doffing helmet WITH assistance?	Ease of doffing helmet WITHOUT assistance?
MK 21	N	8	8	8	8	3
	Mean	4.5	4.8	4.9	4.4	3.7
	SD	0.53	0.71	0.64	1.06	0.58
	Mean–95%CI	4.13	4.26	4.43	3.64	3.01
	Mean+95%CI	4.87	5.24	5.32	5.11	4.32
	N	35				
	Mean	4.5				
	SD	0.78				
	Mean–95%CI	4.28				
	Mean+95%CI	4.80				

Table 3 (cont.). Descriptive Statistics of Ratings of Dress-out Characteristics for MK 21 and KM 37 Helmets.

		DON AND DOFF				
		Ease of donning neck dam/ring assembly?	Ease of positioning the head cushion?	Ease of donning helmet WITH assistance?	Ease of doffing helmet WITH assistance?	Ease of doffing helmet WITHOUT assistance?
KM 37	N	8	8	8	7	5
	Mean	5.1	5.3	5.1	5.0	4.2
	SD	0.99	0.71	0.83	1.00	1.10
	Mean–95%CI	4.44	4.76	4.55	4.26	3.24
	Mean+95%CI	5.81	5.74	5.70	5.74	5.16
	N	36				
	Mean	5.0				
	SD	0.93				
	Mean–95%CI	4.70				
	Mean+95%CI	5.30				

Table 4. Descriptive Statistics of Ratings of Diving Comfort Characteristics for MK 21 and KM 37 Helmets.

		COMFORT WHILE DIVING				
		Overall comfort in terms of buoyancy?	Overall comfort regarding position of your head in the helmet?	Overall comfort of the helmet when picking up something in front of your feet?	Front and back balance of the helmet?	Right and left balance of the helmet?
MK 21	N	8	8	8	8	8
	Mean	4.5	4.3	4.1	4.3	4.4
	SD	0.53	0.71	0.35	0.46	0.52
	Mean–95%CI	4.13	3.76	3.88	3.93	4.02
	Mean+95%CI	4.87	4.74	4.37	4.57	4.73
	N	40				
	Mean	4.3				
	SD	0.52				
	Mean–95%CI	4.14				
	Mean+95%CI	4.46				
KM 37	N	8	8	8	8	8
	Mean	5.3	5.0	4.8	5.1	5.1
	SD	0.71	0.93	0.46	0.64	0.64
	Mean–95%CI	4.76	4.36	4.43	4.68	4.68
	Mean+95%CI	5.74	5.64	5.07	5.57	5.57
	N	40				
	Mean	5.1				
	SD	0.68				
	Mean–95%CI	4.84				
	Mean+95%CI	5.26				

Table 5. Descriptive Statistics of Ratings of Equipment Access and Operability Characteristics for MK 21 and KM 37 Helmets.

		ACCESS AND OPERABILITY									
		Accessibility and operability of adjustable neck pad assembly?	Accessibility and operability of adjustable chin support?	Seal between your face and oral-nasal mask in a 45° face-down position?	Ability of the helmet faceplate to remain clear while at rest?	Ability of air train to clear faceplate?	Accessibility and operability of demand regulator adjustment knob ("Dial-a-Breath")?	Accessibility and operability of the nose-clearing device?	Ease of dewatering the oral-nasal mask?	Accessibility and operability of the steady flow?	Water infiltration through regulator exhaust?
MK 21	N	7	6	8	8	8	8	8	8	8	7
	Mean	4.1	4.2	4.3	3.6	4.6	4.5	4.4	4.5	4.9	4.1
	SD	0.69	1.17	1.04	0.74	0.52	0.76	0.52	0.53	0.35	0.69
	Mean –95% CI	3.63	3.23	3.53	3.11	4.27	3.98	4.02	4.13	4.63	3.63
	Mean +95% CI	4.65	5.10	4.97	4.14	4.98	5.02	4.73	4.87	5.12	4.65
	N	76									
	Mean	4.3									
	SD	0.76									
	Mean –95% CI	4.16									
	Mean +95% CI	4.50									

Table 5 (cont.). Descriptive Statistics of Ratings of Equipment Access and Operability Characteristics for MK 21 and KM 37 Helmets.

		ACCESS AND OPERABILITY									
		Accessibility and operability of adjustable neck pad assembly?	Accessibility and operability of adjustable chin support?	Seal between your face and oral-nasal mask in a 45° face-down position?	Ability of the helmet faceplate to remain clear while at rest?	Ability of air train to clear faceplate?	Accessibility and operability of demand regulator adjustment knob ("Dial-a-Breath")?	Accessibility and operability of the nose-clearing device?	Ease of dewatering the oral-nasal mask?	Accessibility and operability of the steady flow?	Water infiltration through regulator exhaust?
KM 37	N	8	8	8	8	8	8	8	8	8	8
	Mean	4.6	4.9	5.1	4.6	5.0	5.3	5.0	5.1	5.3	5.5
	SD	0.74	0.64	0.83	0.74	0.53	0.71	0.53	0.64	0.71	0.53
	Mean–95%CI	4.11	4.43	4.55	4.11	4.63	4.76	4.63	4.68	4.76	5.13
	Mean+95%CI	5.14	5.32	5.70	5.14	5.37	5.74	5.37	5.57	5.74	5.87
	N	80									
	Mean	5.0									
	SD	0.68									
	Mean–95%CI	4.89									
	Mean+95%CI	5.19									

Table 6. Descriptive Statistics of Ratings for Vision while Diving and for Noise Levels and Communication Characteristics with MK 21 and KM 37 Helmets.

		VISION WHILE DIVING					NOISE LEVELS AND COMMUNICATION	
		Ability to look to right?	Ability to look to left?	Ability to look directly over your head?	Ability to look directly at your feet?	Diversion of exhaust bubbles away from vision?	Ease of speaking while wearing the helmet?	Level of noise during maximum steady flow use?
MK 21	N	7	8	8	8	8	8	8
	Mean	4.4	4.4	4.1	4.4	4.5	4.6	4.5
	SD	0.53	0.52	0.35	0.52	0.53	0.52	0.76
	Mean–95%CI	4.03	4.02	3.88	4.02	4.13	4.27	3.98
	Mean+95%CI	4.82	4.73	4.37	4.73	4.87	4.98	5.02
	N	39					16	
	Mean	4.4					4.6	
	SD	0.49					0.63	
	Mean–95%CI	4.21					4.25	
	Mean+95%CI	4.51					4.87	
KM 37	N	8	8	8	8	8	6	8
	Mean	4.9	4.9	5.0	4.9	5.0	4.3	4.4
	SD	0.64	0.64	0.53	0.64	0.76	0.52	0.52
	Mean–95%CI	4.43	4.43	4.63	4.43	4.48	3.92	4.02
	Mean+95%CI	5.32	5.32	5.37	5.32	5.52	4.75	4.73
	N	40					14	
	Mean	4.9					4.4	
	SD	0.62					0.50	
	Mean–95%CI	4.73					4.10	
	Mean+95%CI	5.12					4.62	

Table 7. Descriptive Statistics of Ratings of Respiratory Effort for MK 21 and KM 37 Helmets.

		RATING OF RESPIRATORY EFFORT							
		Effort required to breathe while standing upright at rest and not wearing the helmet?	Effort required to breathe while diving and standing upright at rest?	Effort required to breathe while diving and in a 45° face-down position at rest?	Effort required to breathe while diving and in a 45° face-up position at rest?	Effort required to breathe while diving and in a prone position at rest?	Effort required to breathe while diving and in a supine position at rest?	Effort required to breathe while diving and standing upright while performing moderate exercise?	Effort required to breathe while diving and standing upright while performing heavy exercise?
MK 21	N	8	8	8	8	8	8	8	7
	Mean	0.4	0.8	0.8	1.0	1.0	0.8	0.9	0.9
	SD	0.44	0.37	0.38	0.46	0.46	0.38	0.23	0.19
	Mean–95%CI	0.07	0.55	0.49	0.68	0.68	0.49	0.71	0.79
	Mean+95%CI	0.68	1.07	1.01	1.32	1.32	1.01	1.04	1.07
	N	63							
	Mean	0.8							
	SD	0.41							
	Mean–95%CI	0.71							
	Mean+95%CI	0.91							

Table 7 (cont.). Descriptive Statistics of Ratings of Respiratory Effort for MK 21 and KM 37 Helmets.

		RATING OF RESPIRATORY EFFORT							
		Effort required to breathe while standing upright at rest and <u>not</u> wearing the helmet?	Effort required to breathe while diving and standing upright at rest?	Effort required to breathe while diving and in a 45° face-down position at rest?	Effort required to breathe while diving and in a 45° face-up position at rest?	Effort required to breathe while diving and in a prone position at rest?	Effort required to breathe while diving and in a supine position at rest?	Effort required to breathe while diving and standing upright while performing moderate exercise?	Effort required to breathe while diving and standing upright while performing heavy exercise?
KM 37	N	7	7	7	7	7	7	7	5
	Mean	0.3	0.7	0.7	0.7	0.7	0.6	0.7	0.7
	SD	0.39	0.27	0.27	0.27	0.27	0.35	0.27	0.27
	Mean–95%CI	0.0	0.52	0.52	0.52	0.52	0.32	0.52	0.46
	Mean+95%CI	0.58	0.91	0.91	0.91	0.91	0.83	0.91	0.94
	N	54							
	Mean	0.6							
	SD	0.31							
	Mean–95%CI	0.56							
	Mean+95%CI	0.72							

Table 8. Difference (MK 21 – KM 37) between Ratings of Dress-out Characteristics of MK 21 and KM 37 Helmets. (Note: 999 – missing value)

Diver	DON AND DOFF				
	Ease of donning neck dam/ring assembly?	Ease of positioning the head cushion?	Ease of donning helmet WITH assistance?	Ease of doffing helmet WITH assistance?	Ease of doffing helmet WITHOUT assistance?
1	1	0	–1	–1	1
2	1	1	1	1	999
3	–2	–1	–1	–1	–1
4	2	1	0	999	999
5	1	1	1	1	999
6	1	1	1	1	999
7	1	1	1	0	0
8	0	0	0	4	999
N	8	8	8	7	3
Mean	0.6	0.5	0.3	0.7	0.0
SD	1.19	0.76	0.89	1.70	1.00
Mean–95%CI	–0.20	–0.02	–0.36	–0.55	–1.13
Mean+95%CI	1.45	1.02	0.86	1.98	1.13
N	34				
Mean	0.5				
SD	1.11				
Mean–95%CI	0.10				
Mean+95%CI	0.84				

Table 9. Difference (MK 21 – KM 37) between Ratings of Diving Comfort of MK 21 and KM 37 Helmets.

Diver	COMFORT WHILE DIVING				
	Overall comfort in terms of buoyancy?	Overall comfort regarding position of your head in the helmet?	Overall comfort of the helmet when picking up something in front of your feet?	Front and back balance of the helmet?	Right and left balance of the helmet?
1	1	0	1	2	2
2	1	3	0	0	0
3	–1	–1	0	0	0
4	1	1	1	1	1
5	2	2	1	1	1
6	1	0	1	1	1
7	1	1	0	1	0
8	0	0	1	1	1
N	8	8	8	8	8
Mean	0.8	0.8	0.6	0.9	0.8
SD	0.89	1.28	0.52	0.64	0.71
Mean–95%CI	0.14	–0.14	0.27	0.43	0.26
Mean+95%CI	1.36	1.64	0.98	1.32	1.24
N	40				
Mean	0.8				
SD	0.81				
Mean–95%CI	0.50				
Mean+95%CI	1.00				

Table 10. Difference (MK 21 – KM 37) between Ratings of Equipment Access and Operability of MK 21 and KM 37 Helmets. (Note: 999 – missing value)

	Diver							
	1	2	3	4	5	6	7	8
Accessibility and operability of adjustable neck pad assembly?	2	0	–1	999	1	0	0	1
Accessibility and operability of adjustable chin support?	2	2	0	999	0	–1	999	2
Seal between your face and oral-nasal mask in a 45° face-down position?	1	0	0	0	1	1	0	4
Ability of the helmet faceplate to remain clear while at rest?	0	2	1	0	3	1	0	1
Ability of air train to clear faceplate?	1	0	0	0	1	1	0	0
Accessibility and operability of demand regulator adjustment knob ("Dial-a-Breath")?	1	1	1	0	1	1	0	1
Accessibility and operability of the nose-clearing device?	1	1	1	0	0	1	0	1
Ease of dewatering the oral-nasal mask?	1	0	0	0	1	1	0	2
Accessibility and operability of the steady flow?	1	1	–1	0	0	1	0	1
Water infiltration through regulator exhaust?	1	1	999	1	1	2	1	3

Table 10 (cont.). Difference (MK 21 – KM 37) between Ratings of Equipment Access and Operability of MK 21 and KM 37 Helmets. (Note: 999 – missing value)

	N	Mean	SD	Mean – 95% CI	Mean + 95%CI	N	Mean	SD	Mean – 95% CI	Mean + 95%CI
Accessibility and operability of adjustable neck pad assembly?	7	0.4	0.98	–0.29	1.15					
Accessibility and operability of adjustable chin support?	6	0.8	1.33	–0.23	1.90					
Seal between your face and oral-nasal mask in a 45° face-down position?	8	0.9	1.36	–0.06	1.81					
Ability of the helmet faceplate to remain clear while at rest?	8	1.0	1.07	0.26	1.74					
Ability of air train to clear faceplate?	8	0.4	0.52	0.02	0.73	76	0.7	0.89	0.52	0.92
Accessibility and operability of demand regulator adjustment knob ("Dial-a-Breath")?	8	0.8	0.46	0.43	1.07					
Accessibility and operability of the nose-clearing device?	8	0.6	0.52	0.27	0.98					
Ease of dewatering the oral-nasal mask?	8	0.6	0.74	0.11	1.14					
Accessibility and operability of the steady flow?	8	0.4	0.74	–0.14	0.89					
Water infiltration through regulator exhaust?	7	1.4	0.79	0.85	2.01					

Table 11. Difference (MK 21 – KM 37) between Ratings of Vision and of Noise Levels and Communication Characteristics of MK 21 and KM 37 Helmets while Diving. (Note: 999 – missing value)

Diver	VISION WHILE DIVING					NOISE LEVELS AND COMMUNICATION	
	Ability to look to right?	Ability to look to left?	Ability to look directly over your head?	Ability to look directly at your feet?	Diversion of exhaust bubbles away from vision?	Ease of speaking while wearing the helmet?	Level of noise during maximum steady flow use?
1	1	1	1	1	0	–1	–1
2	0	0	1	1	2	999	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	999	1	1	1	1	999	0
6	1	1	2	2	1	–1	0
7	0	0	1	0	0	0	1
8	1	1	1	–1	0	0	–1
N	7	8	8	8	8	6	8
Mean	0.4	0.5	0.9	0.5	0.5	–0.3	–0.1
SD	0.53	0.53	0.64	0.93	0.76	0.52	0.64
Mean–95%CI	0.03	0.13	0.43	–0.14	–0.02	–0.75	–0.57
Mean+95%CI	0.82	0.87	1.32	1.14	1.02	0.08	0.32
N	39					14	
Mean	0.6					–0.2	
SD	0.68					0.58	
Mean–95%CI	0.35					–0.52	
Mean+95%CI	0.78					0.09	

Table 12. Difference (MK 21 – KM 37) between Ratings of Respiratory Effort of MK 21 and KM 37 Helmets. (Note: 999 – missing value)

	Diver							
	1	2	3	4	5	6	7	8
Effort required to breathe while standing upright at rest and not wearing the helmet?	–0.5	0	0	0	0	999	0	0
Effort required to breathe while diving and standing upright at rest?	–0.5	0.5	0	–0.5	0	999	0	0
Effort required to breathe while diving and in a 45° face-down position at rest?	–0.5	0	0	–0.5	0	999	1	0
Effort required to breathe while diving and in a 45° face-up position at rest?	–1.5	0	0	–0.5	0	999	0	0
Effort required to breathe while diving and in a prone position at rest?	–0.5	0	0	–0.5	0	999	–1	0
Effort required to breathe while diving and in a supine position at rest?	–0.5	0	0	–0.5	0	999	0	0
Effort required to breathe while diving and standing upright while performing moderate exercise?	–0.5	0	0	–0.5	0	999	0	0
Effort required to breathe while diving and standing upright while performing heavy exercise?	–0.5	999	0	–0.5	999	999	0	0

Table 12 (cont.). Difference (MK 21 – KM 37) between Ratings of Respiratory Effort of MK 21 and KM 37 Helmets. (Note: 999 – missing value)

	N	Mean	SD	Mean – 95% CI	Mean + 95%CI	N	Mean	SD	Mean – 95% CI	Mean + 95%CI
Effort required to breathe while standing upright at rest and not wearing the helmet?	7	–0.1	0.19	–0.21	0.07	54	–0.1	0.36	–0.24	–0.05
Effort required to breathe while diving and standing upright at rest?	7	–0.1	0.35	–0.33	0.18					
Effort required to breathe while diving and in a 45° face-down position at rest	7	0.0	0.50	–0.37	0.37					
Effort required to breathe while diving and in a 45° face-up position at rest?	7	–0.3	0.57	–0.71	0.13					
Effort required to breathe while diving and in a prone position at rest?	7	–0.3	0.39	–0.58	0.01					
Effort required to breathe while diving and in a supine position at rest?	7	–0.1	0.24	–0.32	0.04					
Effort required to breathe while diving and standing upright while performing moderate exercise?	7	–0.1	0.24	–0.32	0.04					
Effort required to breathe while diving and standing upright while performing heavy exercise?	5	–0.2	0.27	–0.44	0.04					

DISCUSSION

Diver ratings of the helmets' characteristics numerically favor the KM 37 over the MK 21. The KM 37 is rated slightly better than the MK 21 for doffing and donning, for comfort while diving, for accessibility to parts and operability, for vision, and for requiring less respiratory effort. However, the noise level and communication capability are rated slightly better for the MK 21 than for the KM 37. The KM 37's poorer noise level and communication performance may be attributable to the fact that it is designed to use a nonamplified microphone, while the OSF communication system is designed to use an amplified microphone.

The current comparison does not reveal significant subjective differences between the KM 37 and MK 21 helmets. Assuming that current findings (typically less than 1 point on either scale) are representative of ratings that could be gathered from a larger sampling of divers than that in this study, the magnitude of the differences observed is unlikely to be statistically significant. The modified Borg scale has demonstrated an intraclass correlation coefficient (Rxx') of 0.77 and standard error of measurement (SEM) of 0.95 when three ratings of respiratory discomfort are obtained on a single day.[8] With single ratings for each characteristic, as used in the current study, lower reliability (smaller Rxx') and greater error (larger SEM) in ratings would be expected. If the six-point scale has similar characteristics, the current results do not support the existence of any difference between the performance of the helmets. Similar performance is expected because of their similar design and components.

CONCLUSION

No statistically significant difference was observed between the specific form, fit, and function characteristics of the MK 21 and KM 37 helmets.

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APPENDIX A

HUMAN FACTORS QUESTIONNAIRE FOR DIVING HELMETS

Name of Diver	Helmet Model	Date of Dive

Total Duration of Dive (min)	Depth (fsw)

1. Using the rating scale in the right side of the table below, place an X in the box corresponding to how you would rate each item in regard to the helmet used on your just completed dive.

	Extremely Poor	Poor	Not Quite Adequate	Adequate	Good	Excellent
DON AND DOFF						
Ease of donning neck dam/ring assembly?						
Ease of positioning the head cushion?						
Ease of donning helmet WITH assistance?						
Ease of doffing helmet WITH assistance?						
Ease of doffing helmet WITHOUT assistance?						
COMFORT WHILE DIVING						
Overall comfort in terms of buoyancy?						
Overall comfort regarding position of your head in the helmet?						
Overall comfort of the helmet when picking up something in front of your feet?						
Front and back balance of the helmet?						
Right and left balance of the helmet?						

	Extremely Poor	Poor	Not Quite Adequate	Adequate	Good	Excellent
ACCESS AND OPERABILITY						
Accessibility and operability of adjustable neck pad assembly?						
Accessibility and operability of adjustable chin support?						
Seal between your face and oral-nasal mask in a 45° face-down position?						
Ability of the helmet faceplate to remain clear while at rest?						
Ability of air train to clear faceplate?						
Accessibility and operability of demand regulator adjustment knob ("Dial-a-Breath")?						
Accessibility and operability of the nose-clearing device?						
Ease of dewatering the oral-nasal mask?						
Accessibility and operability of the steady flow?						
Water infiltration through regulator exhaust?						
VISIBILITY WHILE DIVING						
Ability to look to right?						
Ability to look to left?						
Ability to look directly over your head?						
Ability to look directly at your feet?						
Diversion of exhaust bubbles away from vision?						
NOISE LEVELS AND COMMUNICATION						
Ease of speaking while wearing the helmet?						
Level of noise during maximum steady flow use?						

RESPIRATORY EFFORT

In the box next to the questions below, write the number that corresponds to how you would rate that item in regard to your just-completed dive.

	Rating
Effort required to breathe while standing upright at rest and not wearing the helmet?	
Effort required to breathe while diving and standing upright at rest?	
Effort required to breathe while diving and in a 45° face-down position at rest?	
Effort required to breathe while diving and in a 45° face-up position at rest?	
Effort required to breathe while diving and in a prone position at rest?	
Effort required to breathe while diving and in a supine position at rest?	
Effort required to breathe while diving and standing upright performing moderate exercise?	
Effort required to breathe while diving and standing upright performing heavy exercise?	

10	Maximal
9	Very, very severe
8	
7	Very severe
6	
5	Severe
4	Somewhat severe
3	Moderate
2	Slight
1	Very slight
0.5	Very, very slight
0	Nothing at all

APPENDIX B

RATINGS OF DOFF AND DON, COMFORT WHILE DIVING, ACCESS TO PARTS AND OPERABILITY, VISION, AND COMMUNICATION *

		Don and Doff				
Diver	Helmet	Ease of donning neck dam/ring assembly?	Ease of positioning the head cushion?	Ease of donning helmet WITH assistance?	Ease of doffing helmet WITH assistance?	Ease of doffing helmet WITHOUT assistance?
1	MK21	4	5	5	5	3
2		5	5	5	5	999
3		5	5	5	5	4
4		4	4	5	5	999
5		4	4	4	4	999
6		5	5	5	5	999
7		4	4	4	4	4
8		5	6	6	2	999
1	KM37	5	5	4	4	4
2		6	6	6	6	999
3		3	4	4	4	3
4		6	5	5	999	999
5		5	5	5	5	999
6		6	6	6	6	6
7		5	5	5	4	4
8		5	6	6	6	4

* 999 = diver-subject did not provide a rating

		Comfort While Diving				
Diver	Helmet	Overall comfort in terms of buoyancy?	Overall comfort regarding position of your head in the helmet?	Overall comfort of the helmet when picking up something in front of your feet?	Front and back balance of the helmet?	Right and left balance of the helmet?
1	MK21	4	5	4	4	4
2		5	3	5	5	5
3		5	4	4	4	4
4		4	4	4	4	4
5		4	4	4	4	4
6		5	5	4	5	5
7		4	4	4	4	5
8		5	5	4	4	4
1	KM37	5	5	5	6	6
2		6	6	5	5	5
3		4	3	4	4	4
4		5	5	5	5	5
5		6	6	5	5	5
6		6	5	5	6	6
7		5	5	4	5	5
8		5	5	5	5	5

		Access and Operability									
Diver	Helmet	Accessibility and operability of adjustable neck pad assembly?	Accessibility and operability of adjustable chin support?	Seal between your face and oral-nasal mask in a 45° face-down position?	Ability of the helmet faceplate to remain clear while at rest?	Ability of air train to clear faceplate?	Accessibility and operability of demand regulator adjustment knob ("Dial-a-Breath")?	Accessibility and operability of the nose-clearing device?	Ease of dewatering the oral-nasal mask?	Accessibility and operability of the steady flow?	Water infiltration through regulator exhaust?
1	MK 21	3	3	4	4	4	4	4	4	4	4
2		5	3	5	3	5	5	5	5	5	5
3		4	4	4	3	4	3	4	4	5	999
4		999	999	5	5	5	5	5	5	5	5
5		4	5	5	3	4	4	4	4	5	4
6		5	6	5	4	5	5	4	5	5	4
7		4	999	4	4	5	5	5	5	5	4
8		4	4	2	3	5	5	4	4	5	3
1	KM 37	5	5	5	4	5	5	5	5	5	5
2		5	5	5	5	5	6	6	5	6	6
3		3	4	4	4	4	4	5	4	4	5
4		5	5	5	5	5	5	5	5	5	6
5		5	5	6	6	5	5	4	5	5	5
6		5	5	6	5	6	6	5	6	6	6
7		4	4	4	4	5	5	5	5	5	5
8		5	6	6	4	5	6	5	6	6	6

		VISION WHILE DIVING					NOISE LEVELS AND COMMUNICATION	
Diver	Helmet	Ability to look to right?	Ability to look to left?	Ability to look directly over your head?	Ability to look directly at your feet?	Diversion of exhaust bubbles away from vision?	Ease of speaking while wearing the helmet?	Level of noise during maximum steady flow use?
1	MK 21	4	4	4	4	5	5	5
2		5	5	4	4	4	5	4
3		4	4	4	4	4	4	4
4		5	5	5	5	5	5	5
5		999	4	4	4	4	4	5
6		5	5	4	4	5	5	5
7		4	4	4	5	4	4	3
8		4	4	4	5	5	5	5
1	KM 37	5	5	5	5	5	4	4
2		5	5	5	5	6	999	4
3		4	4	4	4	4	4	4
4		5	5	5	5	5	5	5
5		5	5	5	5	5	999	5
6		6	6	6	6	6	4	5
7		4	4	5	5	4	4	4
8		5	5	5	4	5	5	4

Diver	Helmet	RATING OF RESPIRATORY EFFORT							
		Effort required to breathe while standing upright at rest and not wearing the helmet?	Effort required to breathe while diving and standing upright at rest?	Effort required to breathe while diving and in a 45° face-down position at rest?	Effort required to breathe while diving and in a 45° face-up position at rest?	Effort required to breathe while diving and in a prone position at rest?	Effort required to breathe while diving and in a supine position at rest?	Effort required to breathe while diving and standing upright performing moderate exercise?	Effort required to breathe while diving and standing upright performing heavy exercise?
1	MK 21	1	1	1	2	1	1	1	1
2		0	0	0.5	0.5	0.5	0.5	0.5	999
3		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4		0	1	1	1	1	1	1	1
5		0	1	1	1	1	1	1	1
6		0.5	1	1	1	1	1	1	1
7		0	1	0	1	2	0	1	1
8		1	1	1	1	1	1	1	1
1	KM 37	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2		0	0.5	0.5	0.5	0.5	0.5	0.5	999
3		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4		0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5		0	1	1	1	1	1	1	999
6		999	999	999	999	999	999	999	999
7		0	1	1	1	1	0	1	1
8		1	1	1	1	1	1	1	1